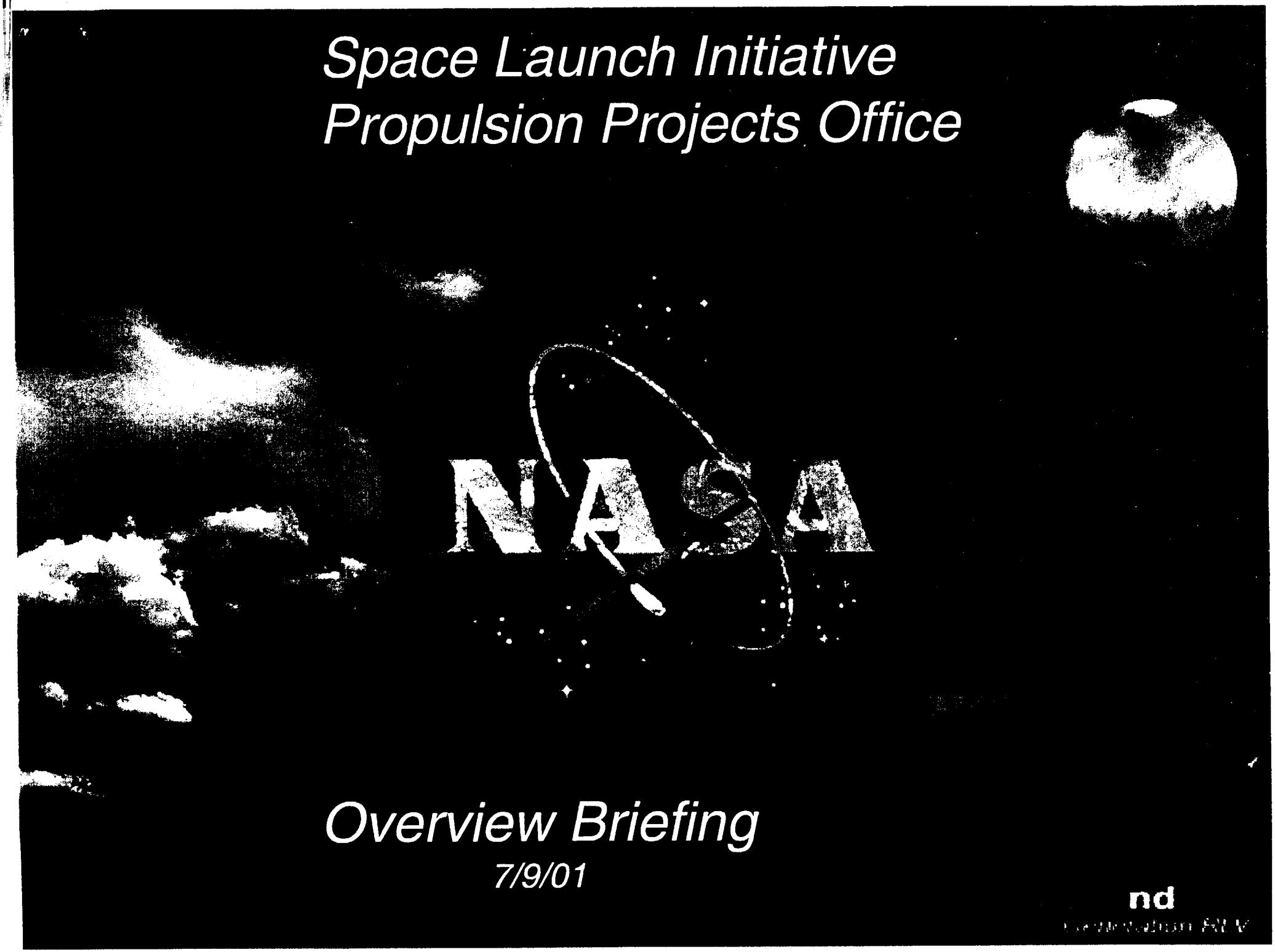
Space Launch Initiative
Propulsion Projects Office



Overview Briefing

7/9/01

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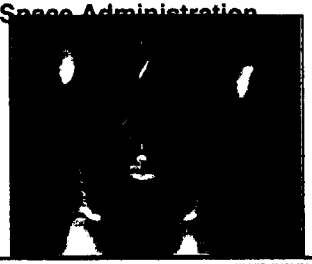
National Aeronautics and Space Administration

Integrated Space Transportation Plan

2nd Generation RLV



Space Shuttle Safety Upgrades

SLI/2nd Gen

Risk Reduction for 2nd Generation Reusable Launch Vehicles

SLI/2nd Gen

Risk Reduction for NASA Unique Systems

SLI/2nd Gen

Alternate Access to the International Space Station Using U.S. Commercial Launch Services

Long Term Investment in 3rd Generation and In-Space Technologies

National Aeronautics and Space Administration

Space Launch Initiative Goals

2nd Generation RLV

The goal of this Space Launch Initiative is for NASA to meet its future space flight needs, including human access to space, using commercial launch vehicles that will improve safety and reliability and reduce cost.

Safety Goal - *Improve safety to better than 1 in 10,000 Loss of Crew*
Cost Goal - *Reduce mission cost to $1000/lb*

Four principles exist:

Commercial Convergence – flying on privately owned and operated launch vehicles;

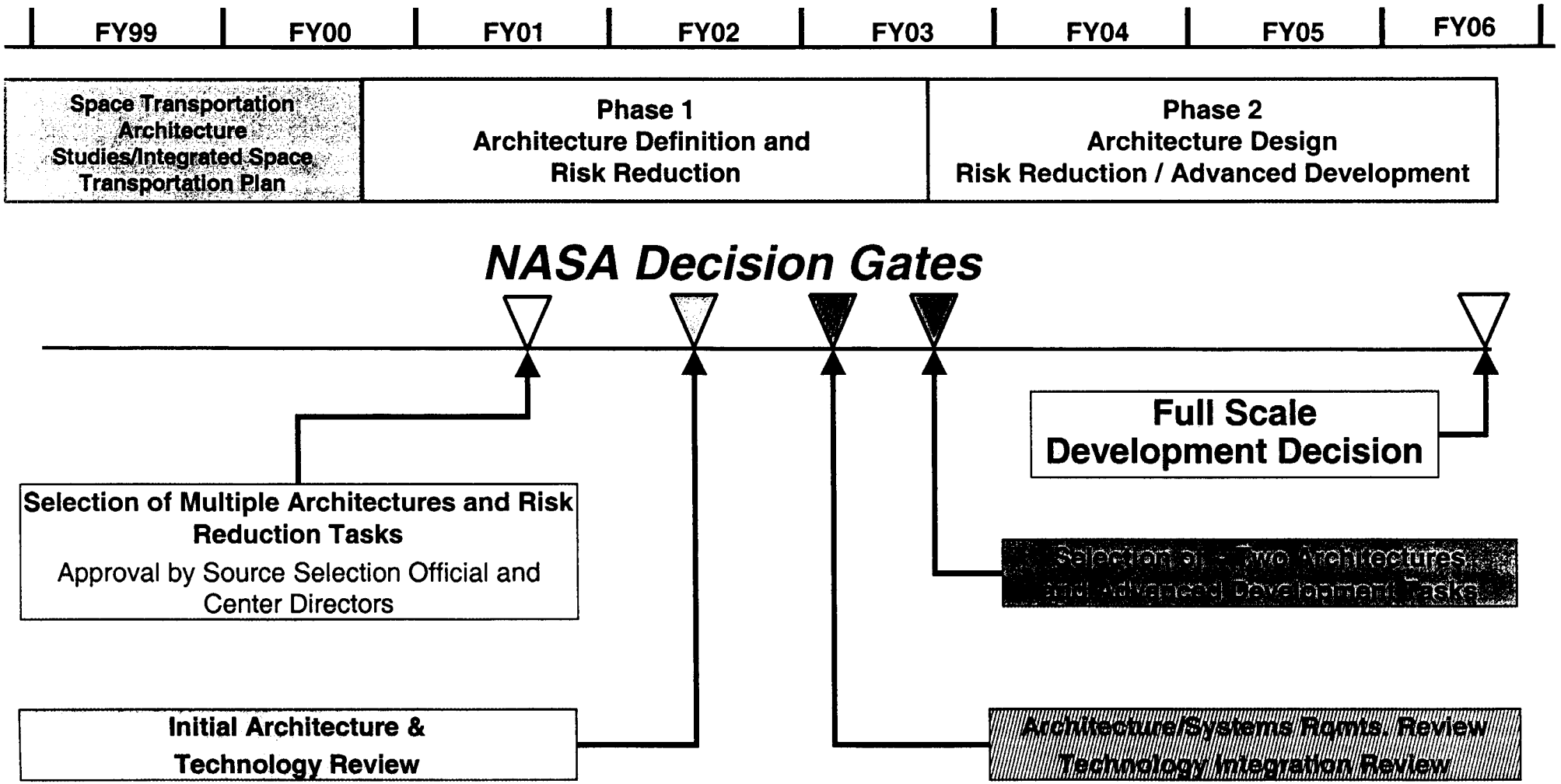
Competition – bringing innovation and new ideas to bear;

Assured Access – ensuring alternate means of getting to space despite launch mishaps;

The Ability to Evolve – adding new capabilities affordably as new mission needs emerge.

2nd Generation RLV Program Overview

Program Phasing and Major Milestones



National Aeronautics and Space Administration

NRA 8-30 Funding

2nd Generation RLV

- Total NRA funding around $900M

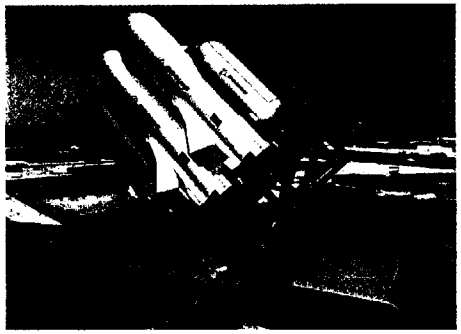
- Total Recommended for Selection $767M
  - FY-01 $150M Recommended in FY01 $94M
  - FY-02 $230M Recommended in FY02 $276M
  - FY03-05 $520M Recommended in FY03-05 $397M

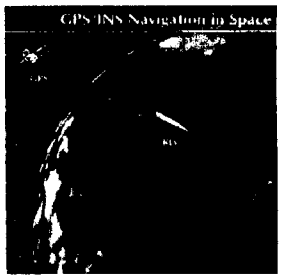
National Aeronautics and Space Administration

SLI Investment Areas

2nd Generation RLV

- **System engineering**
- **Architecture definition and design (5)**
- **Risk Reduction Investments**
  - Airframe (7)
  - Vehicle Subsystems (2)
  - Operations (4)
  - Integrated Vehicle Health Management (3)
  - **Upper Stages (4)**
  - Flight Mechanics (2)
  - **Propulsion (6)**
  - NASA Unique (2)
  - Flight Demonstrators (2)*





22 Partners

$767 million total value

SLI Organizational Summary

National Aeronautics and Space Administration

Mission:
Mature Technology and Architectures to meet program Goals While
- Meeting NASA's needs
- Ensuring Commercial Convergence
- Maximizing competition

Program Office

Manager	*Dennis Smith*
Deputy	*Dan Dumbacher*
Assistant Manager	*Charles Scales*
Chief Engineer	*Vacant*
Tech. Asst.	*B. Morris*
ESA	*Vacant*
MSA	*J. Holland*

Consultants
E.G. F. Wojtalik, G. Oliver, B. Lindstrom
Ext. Rqmts. Assessment Team

Procurement *M. Stiles*

Legal *J. Seemann*

S&MA *Charlie Chesser*

Program Control & Operations
Rose Allen, Manager
Vacant, Deputy

Mission: Ensure Efficient Use of Funds through Cost Control oversight of Projects; Develop Integrated Budget Requirements to maximize investment payoff
• Overall Budget Req. and Integration
Program Cost Control and Management
Administrative Operations

Program Integration & Risk Management
Danny Davis, Manager
Bart Graham, Deputy for Risk Mgmt

-Provide Programmatic integration
Coord & Manage procurement activities
- Lead Risk management
  - Facilitate Project Reporting
  - Ensure standard project mgmt practices

Sys. Engineering, & Integration
Dale Thomas, Manager
Chuck Smith, Deputy

Mission: Provide Technical Integration for the program assuring goals
- In-house Architecture analysis preliminary design
- Integrated tools development
- Technology pay-off analysis
- Government estimates of architectures (cost confidence)
- In-house trade studies
- Systems Engineering Processes
- Safety and Reliability Analysis
- Requirements Development and Flowdown
- Mission Needs development and integration

Systems Analysis And Tool Development

Systems Definition

System Requirements

Architecture Definition
Steve Creech, Manager

IC1	*Bob Armstrong*
IC2	*Charlie Dill*
IC3	*Pete Rodriguez*
CTV	*Steve Davis*
Alternate Access	

Mission: Mature Competing Industry Integrated Architectures to meet the program goals
- Define and Mature architectures to meet goals
- Define architecture specific tech. requirements
- Develop market and business case

Risk Reduction Projects

Mission: Implement Technology and Advanced Development Projects To Support goals - Hardware Development
- Aligned by technology area to leverage investments to Support Multiple Architectures - Maximizes competition at both the architecture and technology level

Airframe (LaRC)

Manager	*D. Bowles (Act.)*
Dep. Mgr.	*Pending*
LSE	*Pending*

Operations (KSC)

Manager	*Scott Huzar*
Dep. Mgr.	*Pending*
LSE	*KSC*

Flight Mechanics (MSFC)

Manager	*Vacant*
Dep. Mgr.	*Vacant*
LSE	*J. Mulqueen (act.)*

NASA Unique (JSC)

Manager	*Doug Whitehead*
LSE	*Vacant*

Subsystems (GRC)

Manager	*Mike Skor*
Dep. Mgr.	*Fred Elliot*
LSE	*Tom Hill*

IVHM (ARC)

Manager	*Bill Kahle*
Asst. Mgr./	*Kevin Flynn*
LSE	

Propulsion (MSFC)

Manager	*Garry Lyles*
Dep. Mgr.	*Steve Richards*
Lead Sys. Engr.	*George Young*

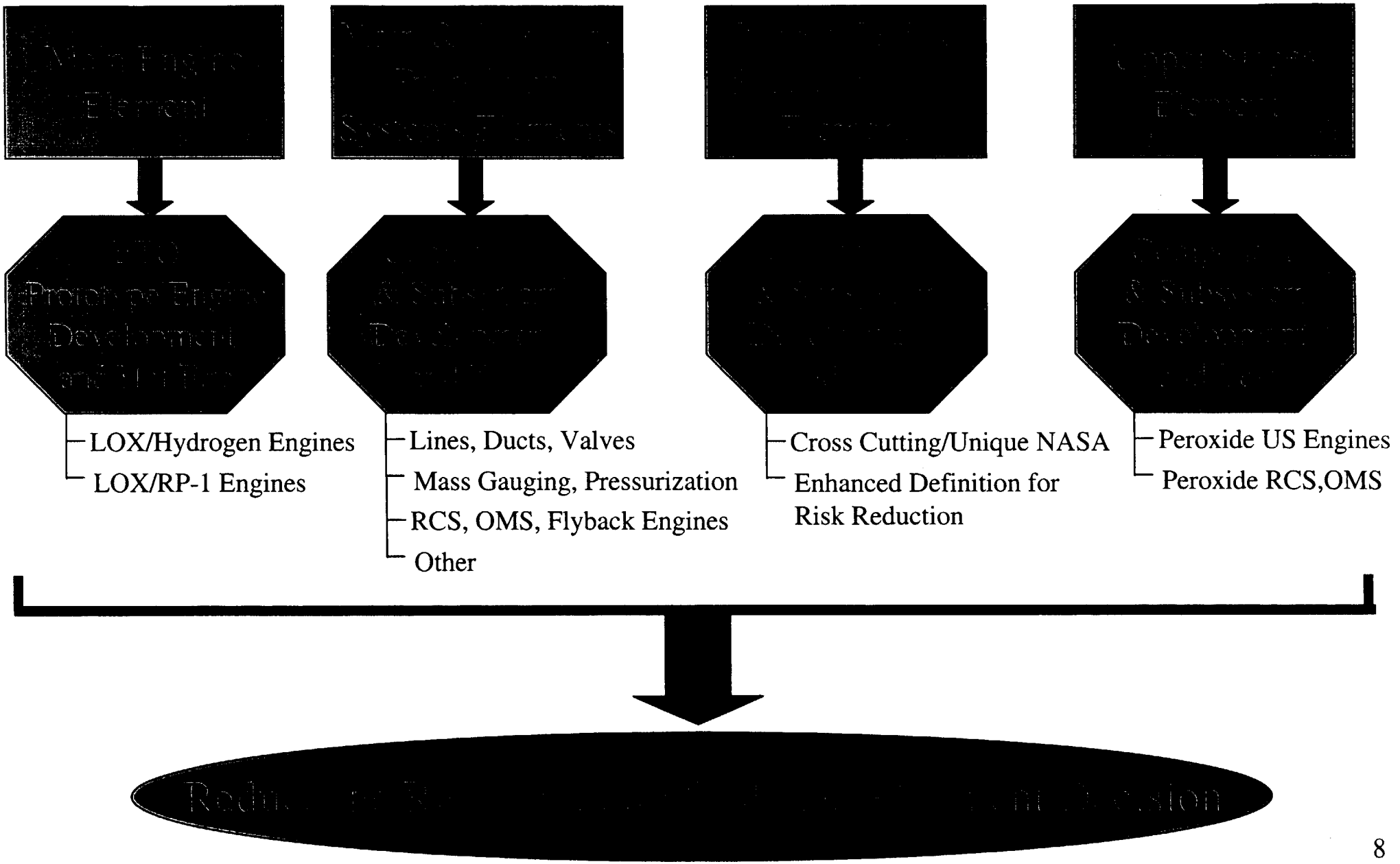
Flt. Demos & Exp. Integ. (MSFC)

Manager	*ADVERTISED Outside hire*

National Aeronautics and Space Administration

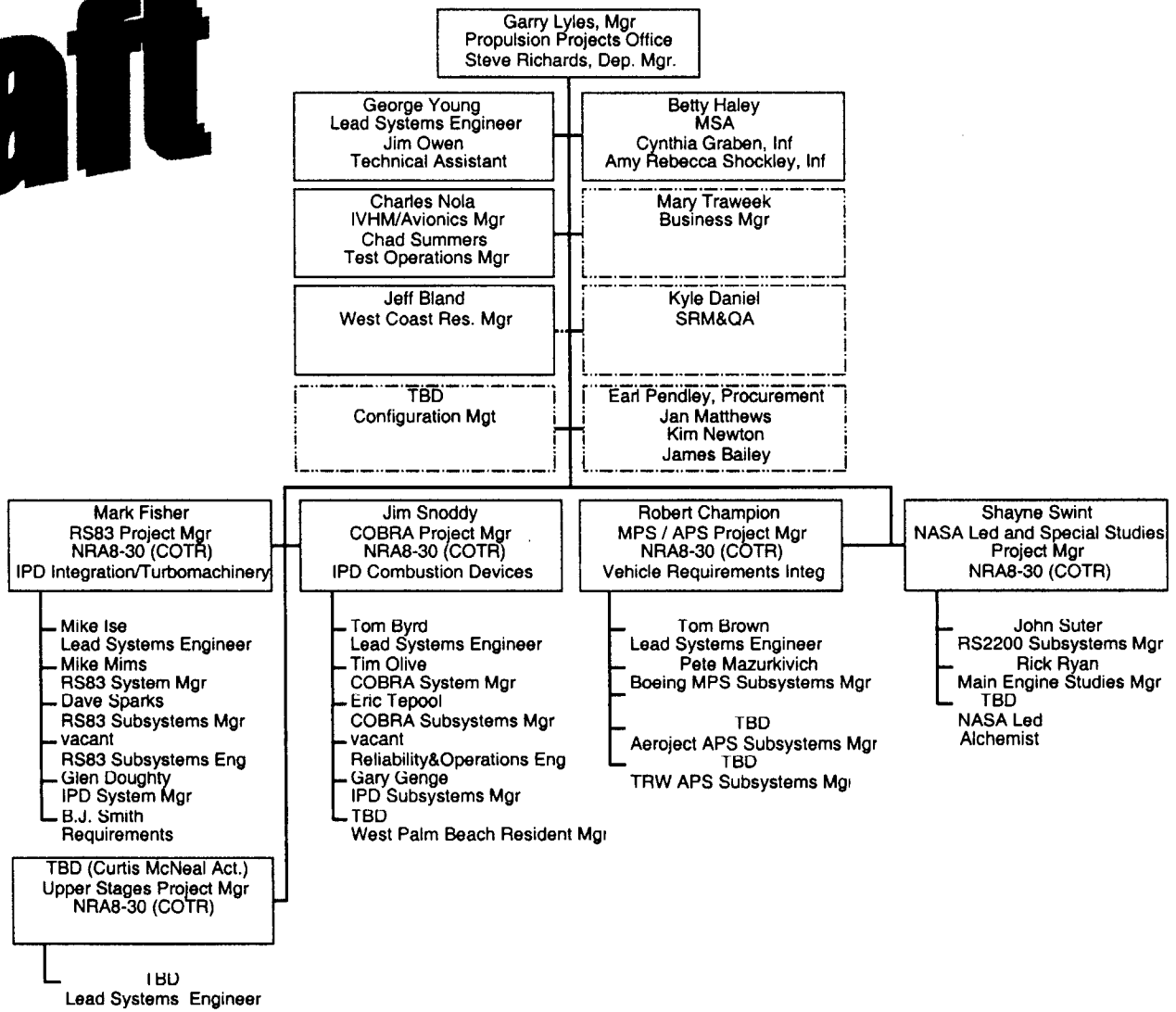
Propulsion Projects Overview

2nd Generation RLV



Organization

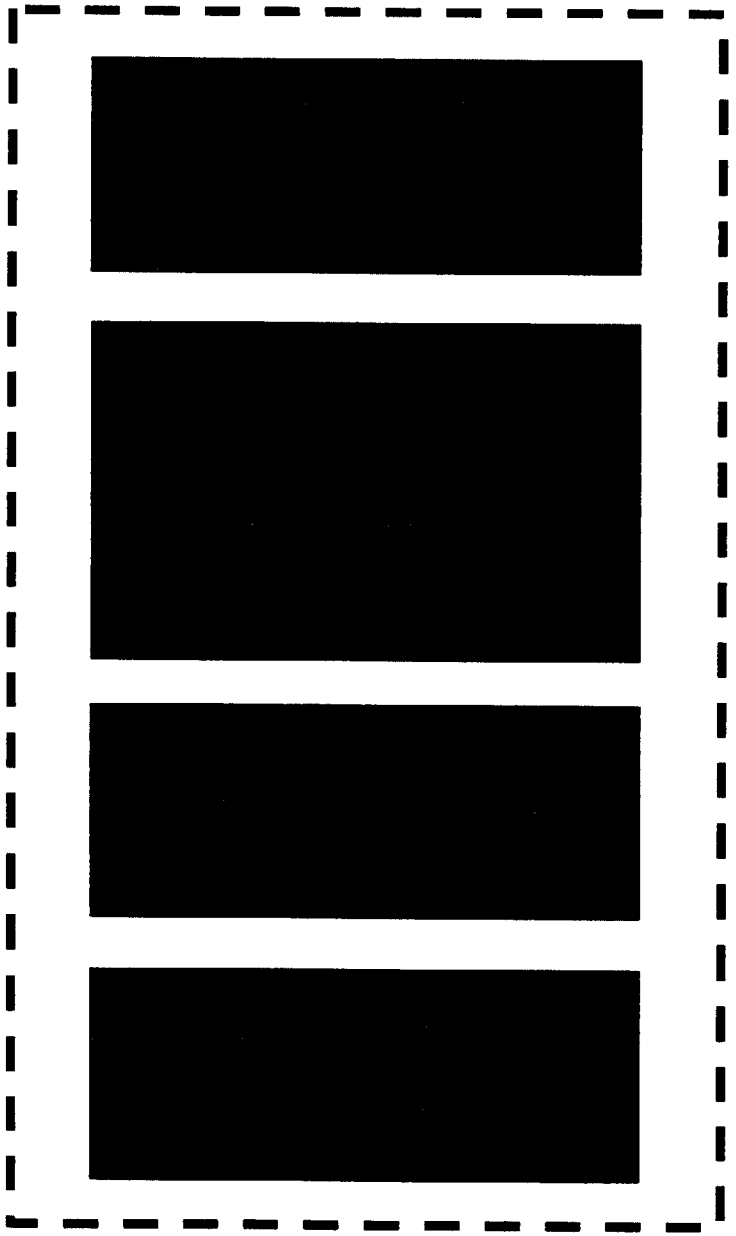
Draft



National Aeronautics
and Space Administration

Current Propulsion Content

2nd Generation RLV

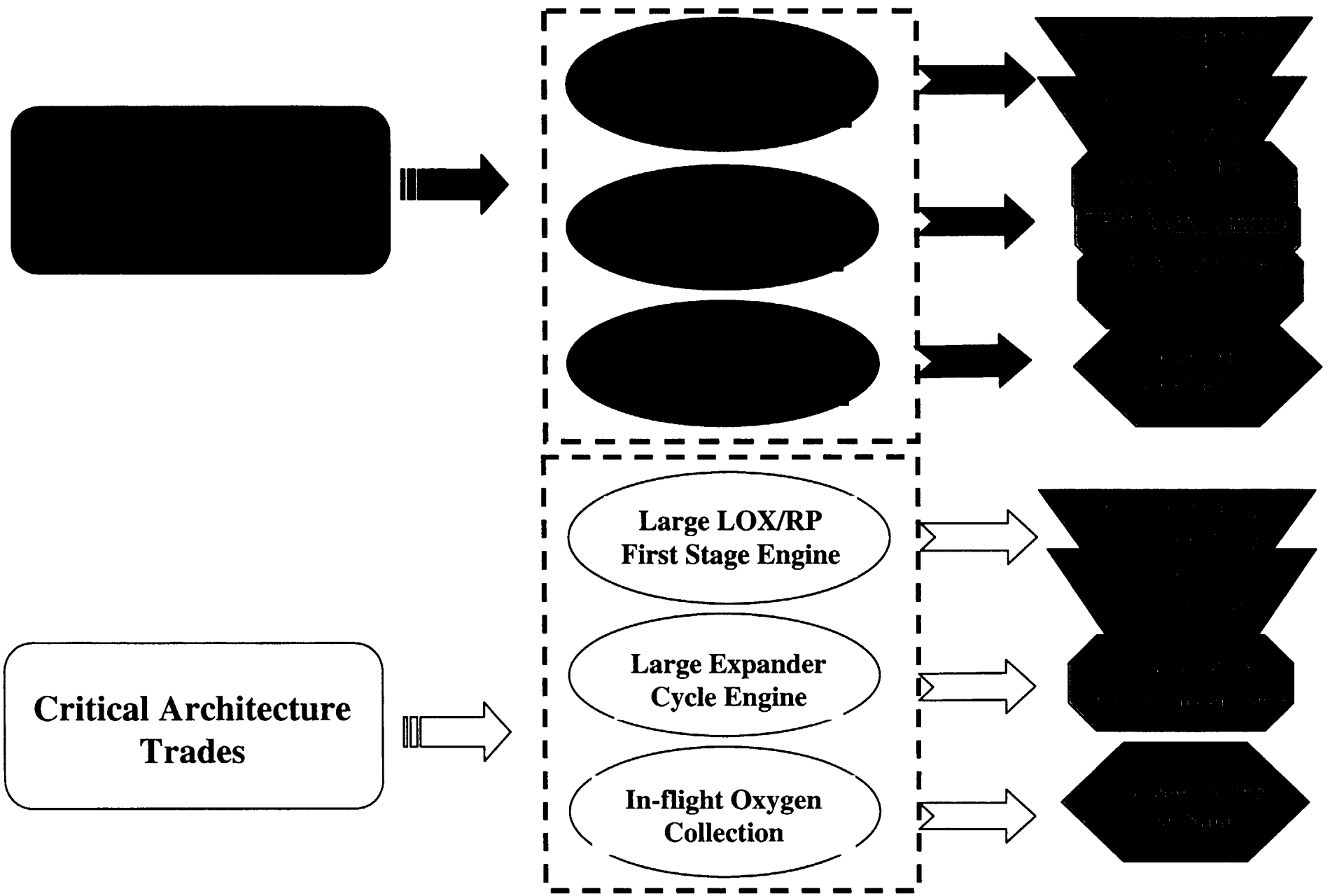


Managed by Propulsion Projects Office

National Aeronautics and Space Administration

Critical Needs Roadmap for NRA 8-30

2nd Generation RLV



Main Engine Prototypes

National Aeronautics and Space Administration

Propulsion Projects Main Engine

2nd Generation RLV

- **Task Title:** RS-83 Main Engine Prototype
- **Company / Task Manager:** Boeing Rocketdyne/John Vilja
- **Government Point of Contact:** Mark Fisher, Project Manager
- **Total Program Cost:** $62.737 M
- **Technical Description:**
  - Subscale pre-burner injector tests at MSFC
  - Pump components water flow testing at MSFC
  - Advanced Valve technology testing at MSFC
  - Integrated Vehicle Health Monitoring engine architecture and algorithm development
  - Engine component design through CDR
  - Engine system design through CDR
- **Task Milestones / Products:**
  - 5/21/01 Authority to Proceed (ATP)
  - 8/15/01 System Requirements Review (SRR)
  - 3/02 Design Concept Review (End of Base Period)
  - 10/02 Preliminary Design Review (PDR)
  - 5/03 Critical Design Review (CDR) (End of Option 1)

National Aeronautics and Space Administration

Propulsion Projects Main Engine

2nd Generation RLV

- **Task Title:** COBRA Main Engine Project
- **Company / Task Manager:** P&W and AJ Propulsion Associates/Rick Bachtel
- **Government Point of Contact:** Jim Snoddy/MSFC
- **Total Program Cost:** $125.3M
- **Technical Description:**
  - COBRA Engine Components through CDR and Engine System through IDR
  - COBRA Subscale Testing (40k)
    - Preburner, Injector, Chamber, LOX/LH2 Cooled Nozzle
  - COBRA Proto-Type Testing (600k)
    - Preburner @SSC
    - Powerhead @P&W
      - Powerball, Preburner, Valves, Modified HPOTP/HPFTP
  - COBRA Proto-Type Hardware
    - Powerball, Preburner, Valves, Modified HPOTP & HPFTP, LOX Boost Pump and Nozzle
  - Light Weight Material Development -Discontinuous Reinforce Aluminum (DRA)
    - Plumbing, Valves and Chamber Jacket
  - RLX Subscale Heat Transfer Design and Test
    - 40k Chamber Test @ MSFC
- **Task Milestones / Products:**
  - 05/03 /Powerhead Test and Maturation of enabling and enhancing Technology to TRL 6
  - 03/03 /Combustion Devices Test and Maturation of enabling and enhancing Technology to TRL 5
  - 02/03 /RLX Chamber Test and Maturation of key enabling technology to TRL 5 for heat transfer
  - Various /SRR, PDR & CDR for all Major Components and System

Main Propulsion System and Auxiliary Propulsion Systems Project

National Aeronautics and Space Administration

Propulsion Projects MPS / APS Project

2nd Generation RLV

- **Task Title:** MPS Cross Feed System Risk Reduction
- **Company / Task Manager:** Boeing – Seal Beach / Frank Chandler
- **Government Point of Contact:** Robert Champion (PM) / Pete Mazurkivich (LSSE)
- **Total Program Cost:** $5.1M
- **Technical Description:**
  - The Boeing Main Propulsion System (MPS) Cross Feed System concept utilizes a passive check valve configuration to supply propellant from the booster stage to both the booster and orbiter stage engines. When the booster tanks near depletion, the orbiter tank isolation valves are opened to allow propellant flow from the orbiter tanks. The resulting increase in pressure head causes the check valves to close isolating the booster stage. The booster is then staged, while the orbiter continues to burn with fully loaded propellant tanks. Hardware commonality and smaller vehicle size are the basis for decreased operating and DDT&E costs. MPS Cross Feed technology supports multiple vehicle architecture concepts.
  - This task involves fabricating a new subscale cross feed valve, developing system level models, performing system level water flow testing/demonstrations, verification of system models and providing technology data to (TA-1) architecture/technology assessment activities.

- **Task Milestones / Products:**
  - 1st Q/FY 02 / Preliminary Design Review
  - 3rd Q/FY 02 / Critical Design Review
  - 3rd Q/FY 02 / Cross Feed Test Article Fabrication Complete
  - 3rd Q/FY 02 / Cross Feed Valve Fabrication Complete
  - 4th Q/FY 02 / Water Flow Testing Complete
  - End Option 1 / Flow Transition and Pressurization Model Development Complete
  - End Option 1 / Final Report Complete

Propulsion Projects MPS / APS Project

- **Task Title:** Aerojet LOX/Ethanol Dual Mode Thruster Development and Risk Reduction
- **Company / Task Manager:** Aerojet / John Hidahl
- **Government Point of Contact:** Robert Champion (PM) / Charles Pierce (Technical)
- **Total Program Cost:** $7.608M
- **Technical Description:**
  - Perform risk reduction activities, relative to the development of an operational non-toxic LOX/Ethanol 870/25 lbf (vacuum) dual-mode thruster, which will achieve a Technical Readiness Level (TRL) 6 by GFY 05.
    - Base Period: Perform Development Testing on the existing Kistler OMS engine
    - Option 1 Period: Perform Dual Mode Demonstration Testing
    - Option 2 Period: Develop Dual Mode Engine
  - 3 Dual Mode LOX/Ethanol Engines will be delivered to WSTF for Government-led System Level Testing
- **Task Milestones / Products:**
  - 10/26/01 Test Readiness Review, Kistler OMS Demo Engine Test
  - 03/01/02 Conceptual Design Review, Dual Thrust Engine
  - 05/31/02 PDR, Dual Thrust Engine
  - 11/07/01 Test Readiness Review, Dual Thrust Engine Test
  - 04/24/02 CDR, Dual Thrust Engine
  - 09/05/02 Test Readiness Review, Dual Thrust Acceptance Test
  - 01/05/03 Deliver Dual Thrust Engines to WSTF

National Aeronautics and Space Administration

Propulsion Projects MPS / APS Project

2nd Generation RLV

- **Task Title:** LOX/Ethanol, LOX/LH2 Dual Mode Thruster Development & Risk Reduction
- **Company / Task Manager:** TRW / Jacky Calvignac
- **Government Point of Contact:** Robert Champion (PM) / Charles Pierce (Technical)
- **Total Program Cost:** $10.887M
- **Technical Description:**
  - Perform risk reduction activities, relative to the development of an operational non-toxic LOX/Ethanol and LOX/LH2 870/25 lbf (vacuum) dual-mode thruster, which will achieve a Technical Readiness Level (TRL) 6 by GFY 05.
    - Base Period: Exploratory Testing, Prototype Design, Igniter/Vernier Design
    - Option 1 Period: Igniter/Vernier Testing, Prototype Detailed Design
    - Option 2 Period: Prototype Acceptance Testing, Flight Design
  - Deliver 3 Dual Mode LOX/Ethanol Engines to WSTF for System Level Testing
  - Deliver 3 Dual Mode LOX/LH2 Engines to WSTF for System Level Testing
- **Task Milestones / Products:**

03/031/02	PDR, Prototype Engines
05/31/03	CDR, Prototype Engines
03/31/04	Delivery of LOX/Ethanol Engines to WSTF
11/30/04	Delivery of LOX/LH2 Engines to WSTF
08/31/05	PDR, Flight Design Engines

National Aeronautics and Space Administration

Propulsion Projects MPS / APS Project

2nd Generation RLV

- **Task Title:** NT APS System Level Test Stand
- **Company / Task Manager:** N/A
- **Government Point of Contact:** Robert Champion (PM) / Eric Hurlbert (Technical)
- **Total Program Cost:** $5.713M
- **Technical Description:**
  - Demonstrate LO2/LH2 and LO2/ethanol engines at the system level in Simulated Space and Ground Processing environment to achieve TRL of 6
    - Successful integration of the RCS engines into a flight representative system
      - propellant condition, line diameters, variable line lengths, multiple engines manifolds, instrumentation
    - Reliable Ignition and operation (goal of 500,000 cycles) under flight-like system conditions
    - Automated operation of system and engines in space and ground processing environment
  - Test competing engine designs in a test stand capable of re-configuration between LH2 and ethanol and provide all data to vehicle primes and system data to engine vendors
- **Task Milestones / Products:**
  - 2/17/02 Test Plan and Matrix (DE-008) (Draft at ATP)
  - 2/17/02 Test Stand Dynamic Analysis & Models Report– JSC/BNA-Hou
  - 2/17/02 Cryogenic Feedsystem Breadboard Test Report
  - 2/17/02 Test Stand PDR
  - 7/25/02 Test Stand CDR
  - 4/3/03 Receive all Test stand hardware (minus engines)
  - 4/2/04 Test Readiness review
  - 7/1/05 Test reports DE-020

National Aeronautics and Space Administration

Propulsion Projects MPS / APS Project

2nd Generation RLV

- **Task Title:** Propulsion/Vehicle Requirements Integration
- **Company / Task Manager:** NASA MSFC, TA-8
- **Government Point of Contact:** Robert Champion (PM) / Tom Brown (LSE)
- **Total Program Cost:** NASA In-House Systems Engineering & Integration
- **Technical Description:**
  - Facilitate requirements flow from vehicle architectures to propulsion projects, including main engines, main propulsion system, and auxiliary propulsion system activities.
  - Facilitate requirements flow from propulsion projects, including main engines, main propulsion system, and auxiliary propulsion system activities, to vehicle architectures.
  - Gather and communicate propulsion technology data in support of TA-1 systems engineering assessments

- **Task Milestones / Products:**
  - Milestones of this effort will include the support of architecture/technology assessments, all integrated architecture project reviews, as well as propulsion projects reviews and milestones.

NASA Led

And

Special Studies

Project

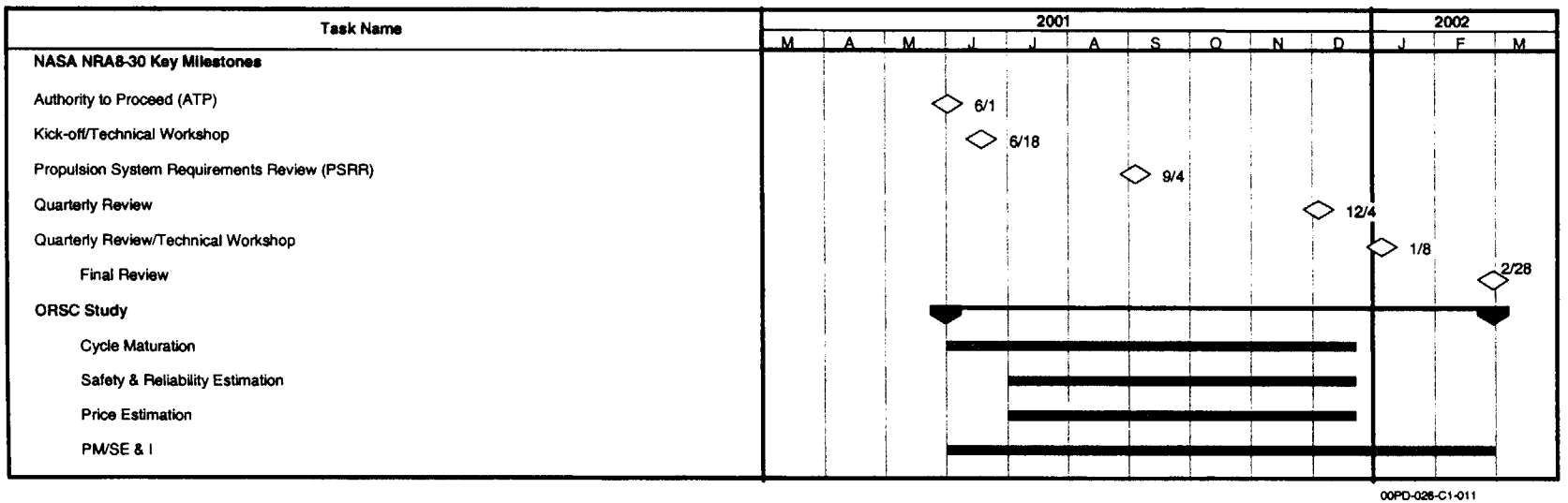
National Aeronautics and Space Administration

Propulsion Projects Engine Study

2nd Generation RLV

- **Task Title:** Oxygen Rich Staged-Combustion LOX/RP Engine Study
- **Company / Task Manager:** Rocketdyne / Brian Anderson
- **Government Point of Contact:** Shayne Swint or Rick Ryan
- **Total Program Cost:** $1.788M
- **Technical Description:**
  - Rocketdyne will conduct a cycle maturation study to further define the engine system concept, the engine performance analysis, safety and reliability analysis, weight estimates, and price estimates. Maturation of the engine system concept will be accomplished through additional analysis and subsystem trades to establish an optimized cycle balance with adequate margin for safety, reliability, and operability. Engine balance iterations and engine system parametric studies will be performed. A control system architecture trade study definition and requirements analysis will be performed. The engine health monitoring approach will be defined.

- **Task Milestones / Products:**

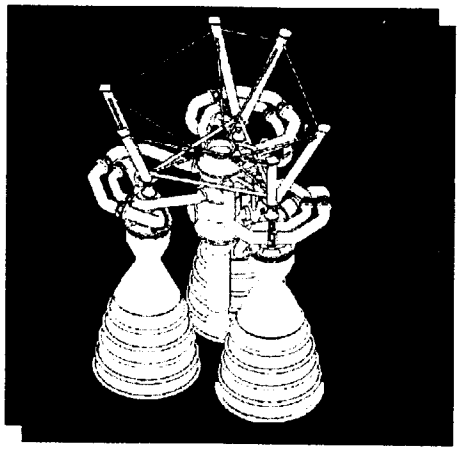


National Aeronautics and Space Administration

Propulsion Projects Engine Study

2nd Generation RLV

- **Task Title:** 1Mlbf LOX/RP-1 Engine Study
- **Company / Task Manager:** TRW / Cathy Gavits
- **Government Point of Contact:** Shayne Swint or Rick Ryan
- **Total Program Cost:** $1.948M
- **Technical Description:**



TRW will conduct a cycle definition & maturation study to further define the engine system concept. This effort will include engine performance analyses, safety and reliability analyses, and assessment to provide weight and price estimates

The design approach and program planning maximize use of the results from TRW's 650 Klbf LOX/LH_2 hot-fire test demonstration work performed to date with NASA. The overall distinguishing attributes of the design that directly address the safety, reliability and cost goals of NASA, are:

- Pintle Injector Main Engine– Robust, simple design with low parts count and scalable
- Pintle Injector Gas Generator – Robust simple design, low parts count, lower pressure, longer cycle life
- Duct Cooled Chamber – simple design, low parts count, no extensive welding, low pressure drop
- Turbopumps – Lower operating pressures, longer life cycle

National Aeronautics and Space Administration

Propulsion Projects Air Enrichment System Study

2nd Generation RLV

- **Task Title:** Air Collection and Enrichment System (ACES)
- **Company / Task Manager:** Andrews Space & Technology / Jason Andrews
- **Government Point of Contact:** Shayne Swint
- **Total Program Cost:** $3.017M
- **Technical Description:**

The Alchemist Air Collection and Enrichment System (ACES) is an enabling technology for the Andrews RLV system architecture which allows airline like operations and promising enhancements to reliability and cost. The ACES allows the production off all required LOX during the turbofan powered cruse phase of the Andrews RLV trajectory. During the course of this study AST will;

- Develop thermodynamic models of the multiple candidate ACES configurations.
- Perform system performance and sizing analyses of candidate configurations.
- Perform component and subsystem level performance and risk reduction analyses.
- Perform system trade studies and develop preferred configuration definition.
- Develop system requirements and concept of operations.
- Develop subsystem and system level test/demonstration plans.

National Aeronautics and Space Administration

Propulsion Projects NLSS Project
NASA Led Tasks

2nd Generation RLV

- NASA-Led Activities are selected to be cross-cutting and relevant to the current set of architectures.
- NASA-Led Activities are considered synergistic with industry led and provide open data to advanced technologies.
- As the Program content narrows the NASA-Led content will be adjusted to provide maximum support to the Program supported architectures.
- Current In-House Tasks
  - **CMC Nozzle/Panel Technology**
  - **GRCop-84 Material Development**
  - **Large Composite Valve**
  - **Staged Combustion Injector Technology**
  - **Gen 2 Turbomachinery tech**
  - **Subscale Combustion Test Bed**
  - **LH2 Densifier Validation**
  - **Leak Detection Technology**
  - **Electromechanical Actuator Technology**

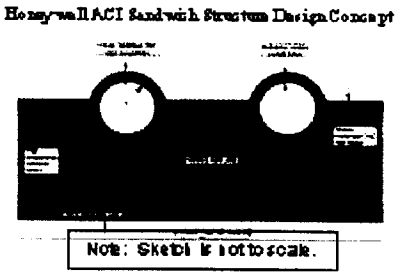
National Aeronautics and Space Administration

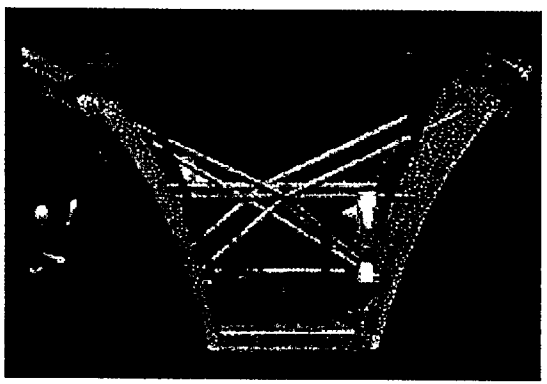
Propulsion Projects NLSS Project
Actively Cooled CMC Nozzle Materials

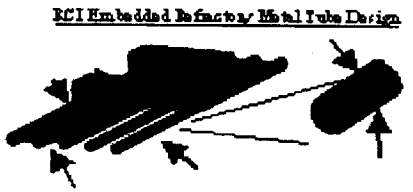
2nd Generation RLV

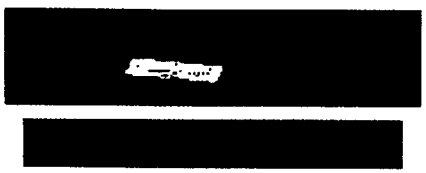
Currently, there are contracts in place with Rockwell Science Center (RSC) Honeywell Advanced Composites Inc. (HACI), Refractory Composites Inc. (RCI) , and Snecma Division SEP (SEP) to develop and demonstrate cooled CMC material systems.

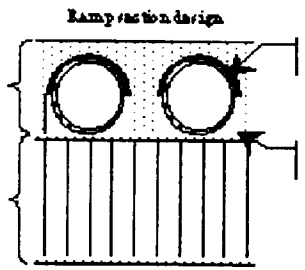
The concepts being demonstrated by these organizations represent the state-of-the-art with respect to actively cooled CMC structures for thermal protection applications.







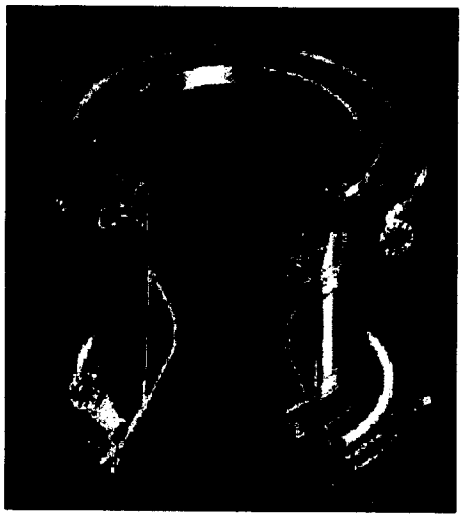

RSC Concept



National Aeronautics and Space Administration

Propulsion Projects NLSS Project
GRCop-84 Materials Development Task

2nd Generation RLV



The GRCop-84 Materials Development Task is charged with developing GRCop-84 (Cu-8 Cr-4 Nb) sheet and plate material for use in rocket engine combustion chamber liners. The task is also developing coatings technology to significantly enhance life and performance of the engines during usage.

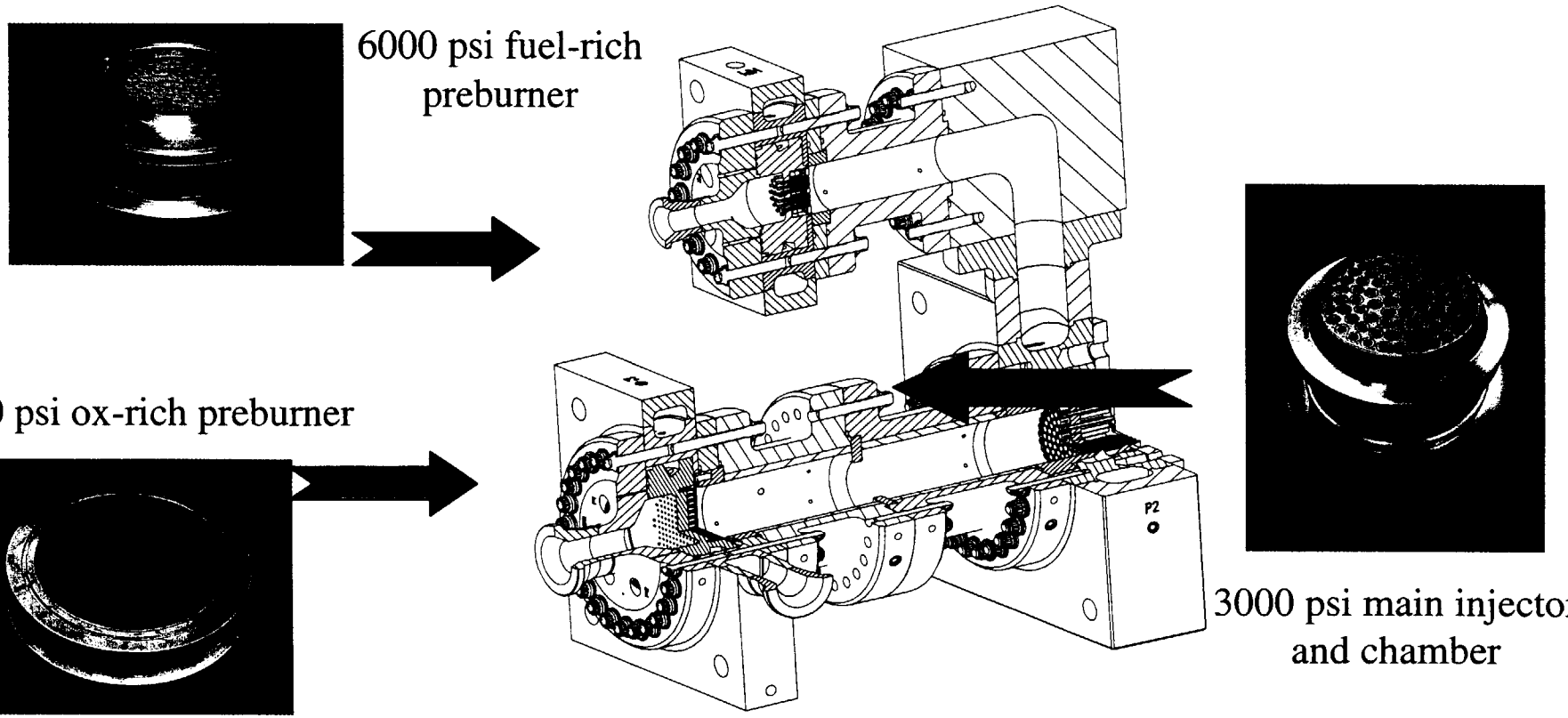
- Products
  - **The program will develop technologies required to produce large sheet and engine parts from sheet product**
    - **Spin forming and platelet technology to produce large combustion chambers**
    - **Coatings technologies to prevent blanching**
- Primary benefits:
  - **Reduced maintenance, life cycle and manufacturing costs with increased safety, scalability, life and performance**

National Aeronautics and Space Administration

Propulsion Projects NLSS Project
Subscale Combustion Devices Testbed

2nd Generation RLV

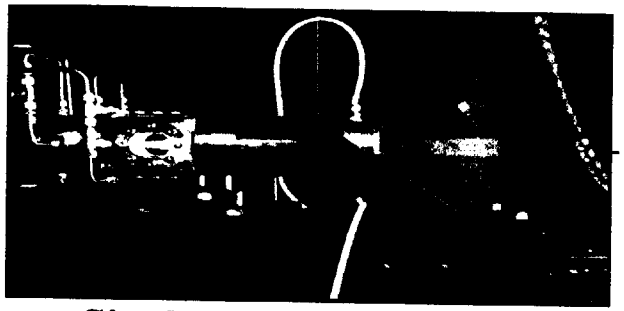
- Products
  - **Robust preburners that eliminate life-limiting effects of transients verified to TRL6**
  - **High thrust/element, low parts-count main chamber injectors demonstrated**
  - **Long-life combustion chambers**
- Benefits
  - **Component flight weight reduction; lower life cycle costs through increased life, increased reliability, shorter full-scale development; and less complex launch site operations**



National Aeronautics and Space Administration

Propulsion Projects NLSS Project
Staged Combustion Main Chamber Injectors

2nd Generation RLV



Single Element Testing

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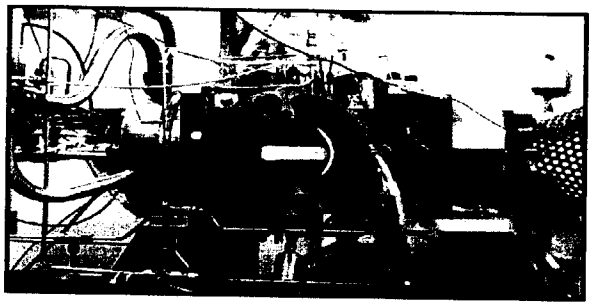
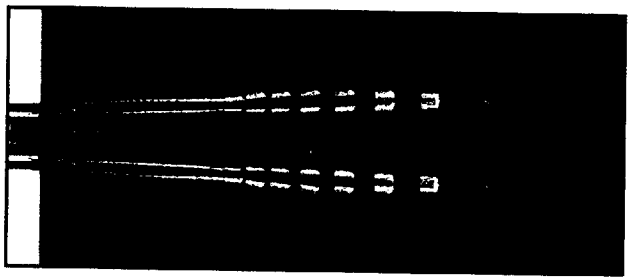


Multi-Element Testing



Validated Analysis Tools

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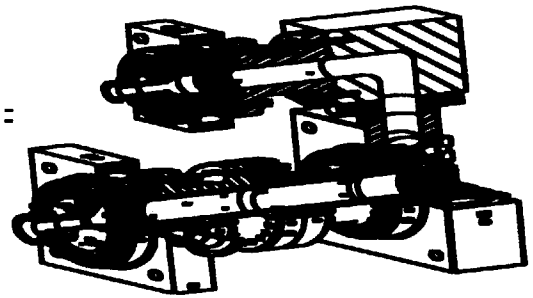
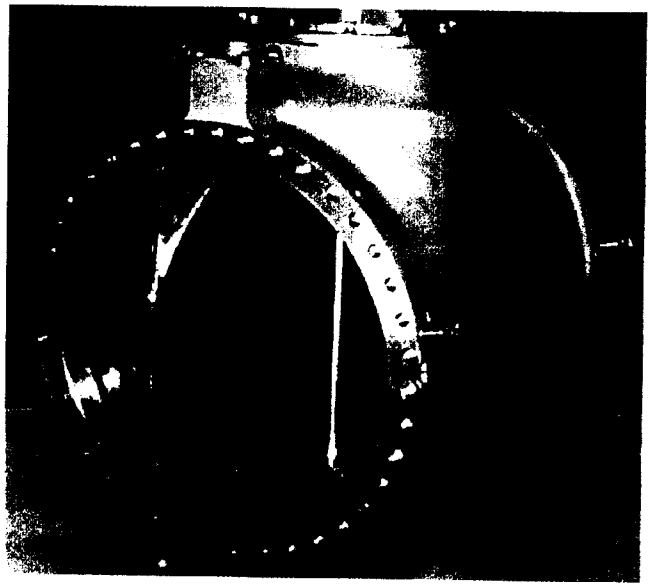


Robust 60K Injector Concepts

- Products
  - Optimized MCC injector concept that fully meets Gen 2 operability, life and performance goals
  - Optimized MCC injector concept(s) that exceed Gen2 requirements
  - Experience in design and operation of LOX-rich preburners
  - Seamless injector design package with tools validated to TL* RL 6-can be used to calculate environments for lie predictions
- Benefits
  - High performing injectors with manageable heat fluxes
  - Lower part count that increases reliability and lowers costs

Propulsion Projects NLSS Project
Large Composite Valve Technology

- Products
  - **A large diameter LH2 valve made from PMC material.**
  - **A series of protective coatings that can be applied to composites and be used in a cryogenic environment. These coatings will increase the materials damage resistance.**



- Benefits
  - **The composite valve technology will enable weight reduction of large MPS components on a vehicle.**
  - **The coating technology will enable the program to operate at a higher confidence level since the risks of impact damage are greatly reduced.**

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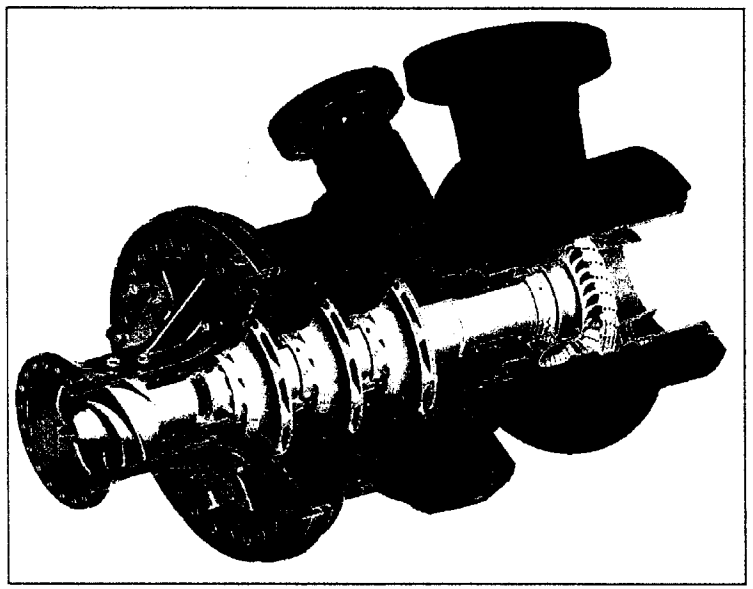
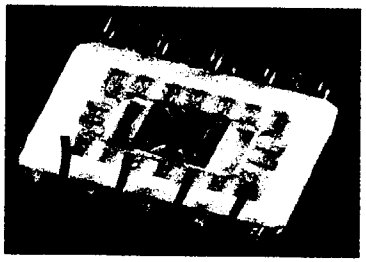
Propulsion Projects NLSS Project
G2RLV Turbomachinery Technology Task

2nd Generation RLV



- Products
  - Incorporate Gen 2 turbomachinery technology into a turbopump demonstrator(s)
- Benefits
  - Demonstrate turbomachinery technology which addresses improved pump performance, turbine performance, seals, materials, and bearings which address engine T/W, decreased costs and improved reliability.

Propulsion Projects NLSS Project
Miniaturized Smart Leak Sensor



Microfabricated Hydrogen Sensor

Hydrogen Sensors on Space Shuttle

Prototype Hydrogen/Oxygen Sensor System with Electronics

Demonstrate Stand-alone Smart Leak Detection System With a Surface Area the Size of Postage Stamp

Integrated Fuel/Oxygen Leak Sensor Assembly

- A microsensor array which includes hydrogen, oxygen, and hydrocarbon sensors
- Produced by MEMS-based technology.
- The array will be incorporated with signal conditioning electronics, power, data storage, and telemetry.
- This final system will be self-contained with the surface area of a postage stamp.

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Propulsion Projects NLSS Project
LH2 Densifier Verification Testing

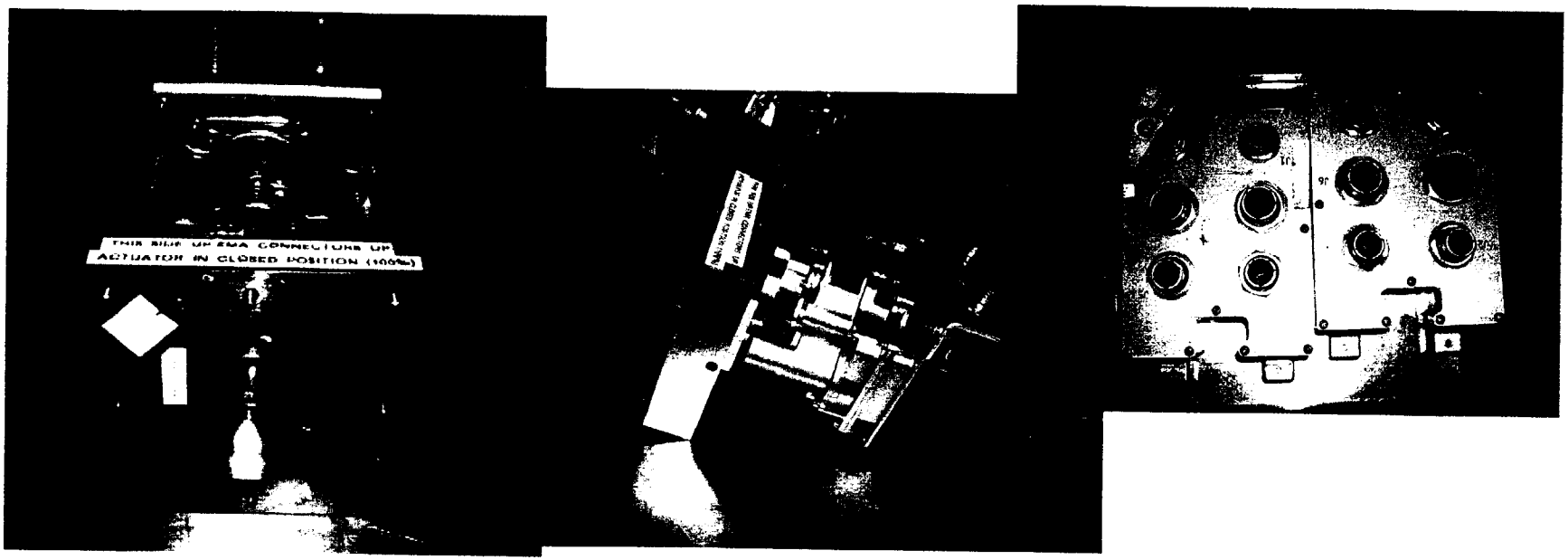
2nd Generation RLV

GRC South 40 Propellant Densification Test Site
Configured for LOX Densification

8 lbm/sec LH2 Densification Unit in storage at GRC Hangar

- Products
  - **Validation of LH2 densification process at large scale (TRL=6)**
  - **Operable (portable) densification skid available for flight experiment or engine test program**
- Benefits
  - **Densification can reduce vehicle weight significantly (RLV studies showed ~18% weight reduction)**

Propulsion Projects NLSS Project
Electromechanical Actuator Technology



- Products
  - **Data package, based on both analysis and test data, demonstrating the technology readiness level of the EMAs that are currently on the X-33 Aerospike Engine.**
- Benefits
  - **Current architectures all indicate the need for EMAs. This data is critical toward developing the confidence required to support EMA utilization for the next generation RLV.**

Upper Stages Project

National Aeronautics and Space Administration

Propulsion Projects Upper Stages Project

2nd Generation RLV

- **Task Title:** Peroxide Coolant Utilization Detonation Studies
- **Company / Task Manager:** Pratt & Whitney/Bill Watkins
- **Government Point of Contact:** Curtis McNeal
- **Total Program Cost:** $424k
- **Technical Description:**
  - Goal: Determine safe operating zone for utilization of 98% peroxide for regenerative cooling of chambers and nozzles
  - Approach: Perform tests of single tube cooling elements to establish critical design factors that lead to peroxide detonation in cooling applications
  - Product: Completion of a design guide that identifies key/critical design variables and establishes safe operating zones for combinations of these variables that prevents the onset of peroxide detonation in the coolant tubes

- **Task Milestones / Products:**
  - 06/12/00 / Program Kickoff Meeting
  - 07/20/01 / Technology Workshop
  - 09/00 / Quarterly Review /Test Matrix review
  - 01/02 / Technology Workshop
  - 02/02 / Final Report

Propulsion Projects Upper Stages Project

- **Task Title:** MCC Material Compatibility Development
- **Company / Task Manager:** Boeing Rocketdyne/Terry Lorier
- **Government Point of Contact:** Curtis McNeal
- **Total Program Cost:** $981,816
- **Technical Description:**
  - Goal: Determine optimum material system for fabrication of regeneratively cooled combustion chamber/nozzles for 98% H2O2/RP propulsion systems
  - Approach:
    - Evaluate a dozen material systems for manufacturability and peroxide compatibility
    - Then test the 6 most promising candidate material systems in a 2-D flow test rig
  - Exit Criteria: Identification of a material system which meets the mission design requirements.

- **Task Milestones / Products:**
  - 05/30/01 / Project kickoff meeting
  - 06/30/01 / Freeze Material Evaluation List
  - 07/20/01 / Technology Workshop
  - 08/30/01 / Quarterly Review
  - 01/02 / Technology Workshop
  - 02/02 / Risk Reduction Review Held
  - 03/02 / Test specimens fabricated
  - 03/02 / Contract Option executed

Propulsion Projects Upper Stages Project

- **Task Title:** Hypergolic Injector Development
- **Company / Task Manager:** Boeing Rocketdyne/Terry Lorier
- **Government Point of Contact:** Curtis McNeal
- **Total Program Cost:** $2.4M
- **Technical Description:**
  - Design, fabrication, and test of an liquid/liquid injector for a hypergolic fuel and 98% peroxide
  - Test to be performed at the Stennis Space Center in 2002.

- **Task Milestones / Products:**
  - 05/30/01 / Project kickoff meeting
  - 07/20/01 / Technology Workshop
  - 08/30/01 / Quarterly Review
  - 01/02 / Technology Workshop
  - 02/02 / Risk Reduction Review Held
  - 03/02 / Test injectors fabricated
  - 01/02 / Contract Option executed
  - 07/02 / Injector Testing Begins

Propulsion Projects Upper Stages Project

- **Task Title:** Integrated Fluid/Gas Controller Conceptual Development
- **Company / Task Manager:** Moog/Marc Chaves
- **Government Point of Contact:** Curtis McNeal
- **Total Program Cost:** $501,458
- **Technical Description:**
  - Engineering trade study of an integrated fluid/gas controller for a peroxide/RP upper stage engine
  - Moog will supply component level analysis and conceptual design, Boeing Rocketdyne will supply engine system level analysis and evaluation
  - New controller is to result in a safer operation thru elimination of leak paths and maintenance operations
  - New controller is to result in lower cost thru part reduction and functional integration
  - New controller is to result in higher reliability thru part reduction and functional integration

- **Task Milestones / Products:**
  - 05/30/01 / Project Kick off Meeting held
  - 07/20/01 / Technology Workshop
  - 08/30/01 / Requirements Freeze/ Quarterly Review
  - 1/02 / Final Study Result Available

National Aeronautics and Space Administration

Propulsion Projects Upper Stages Project

2nd Generation RLV

- **Task Title:** Catalysts Sensitivity Testing
- **Company / Task Manager:** General Kinetics/Eric Wernimont
- **Government Point of Contact:** Curtis McNeal
- **Total Program Cost:** $298,656
- **Technical Description:**
  - Tests of multiple catalyst systems with elevated levels of contaminants and stabilizers to determine their sensitivity levels to poisoning
  - Boeing Rocketdyne and General Kinetics catalyst beds will be tested as a minimum. Aerojet and PCI catalyst beds may be tested
  - The initial list of contaminants and stabilizers include carbon, phosphate, aluminum, stainless steel trace materials, tin, and nitrates. Also being considered is chloride.

- **Task Milestones / Products:**
  - 05/31/01 / Project Kickoff meeting held
  - 06/30/01 / Test plan complete
  - 07/30/01 / Test set-up complete
  - 08/30/01 / Test set-up and procedures validated
  - 09/28/01 / Baseline Tests complete
  - 01/02 / Sensitivity tests complete
  - 02/02 / Draft peroxide procurement specification delivered.

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Propulsion Projects Upper Stages Project

2nd Generation RLV

- **Task Title:** Advanced Turbopump Demonstration
- **Company / Task Manager:** Boeing Rocketdyne/Terry Lorier
- **Government Point of Contact:** Curtis McNeal
- **Total Program Cost:** $8.358M
- **Technical Description:**
  - Development of an advanced catalyst system for decomposition of 98% peroxide with long life consistent with the reusable mission requirements of the 2nd Generation RLV.
  - Development of an advanced torch igniter for initiation of MCC combustion using liquid/liquid injection of 98% peroxide and RP fuel
  - Development and demonstration of an advanced gas generator driven turbopump for 98% peroxide and RP fuels

- **Task Milestones / Products:**
  - 06/13/00 / Phase II Catalyst tests begin
  - 06/28/01 / Turbopump Critical Design Review
  - 07/18/01 / Phase II Catalyst tests complete
  - 09/01 / Gas Generator tests begin
  - 01/02 / Turbopump assembly begins
  - 03/02 / Turbopump testing begins
  - 06/02 / Cooperative agreement complete

National Aeronautics and Space Administration

Propulsion Projects Overview

2nd Generation RLV